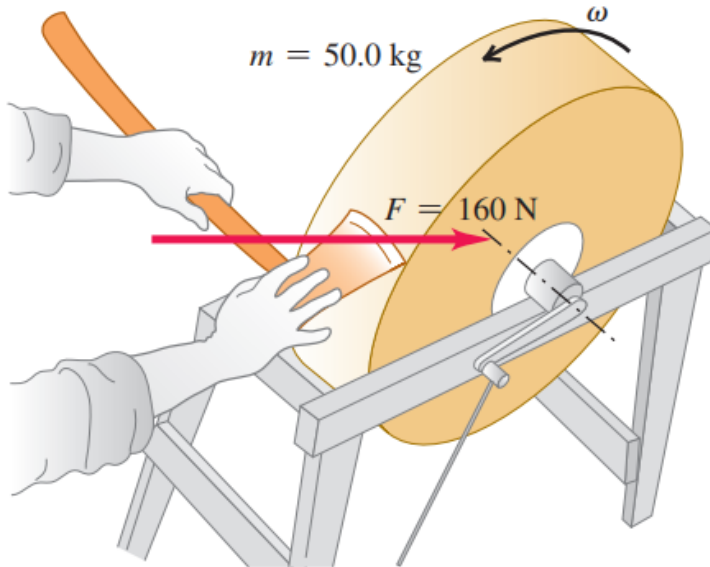


Question 1:

A 50.0 kg grindstone is a solid disk 0.520 m in diameter. You press an ax down on the rim with a normal force of 160 N as shown in figure. The coefficient of kinetic friction between the blade and the stone is 0.60, and there is a constant friction torque of $6.50 \text{ N} \cdot \text{m}$ between the axle of the stone and its bearings. How much time does it take the grindstone to come from 120 rev/min to rest if it is acted on by the axle friction alone?

A. 4.86s

✓ B. 3.27s

C. 5.23s

D. 6.86s

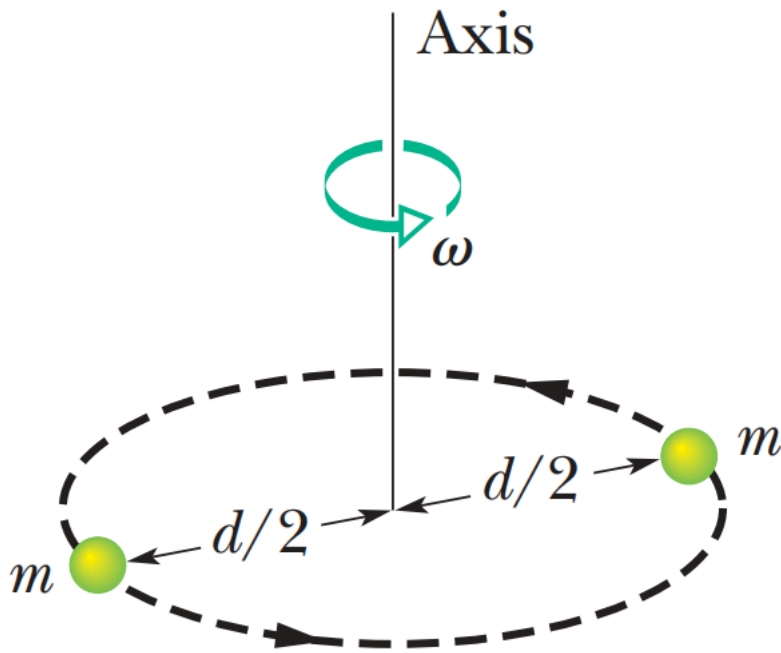
$$I_{\text{disk}} = \frac{1}{2}MR^2 = 1.69 \text{ kg} \cdot \text{m}^2$$

$$\omega_0 = 120 \text{ rev/min} = 4\pi \text{ rad/s}$$

$$\alpha = \frac{\tau}{I} = \frac{6.50}{1.69} = 3.85 \text{ rad/s}^2$$

$$\therefore t = \frac{\omega_0}{\alpha} = \frac{4\pi}{3.85} = 3.27 \text{ s}$$

B

Question 2:

A diatomic gas molecule consists of two atoms of mass m separated by a fixed distance d rotating about an axis as indicated in figure. Assuming that its angular momentum is quantized as in the Bohr model for the hydrogen atom, find the possible quantized rotational energies.

$$I = \sum mr^2 = 2 \cdot m \left(\frac{d}{2}\right)^2 = \frac{1}{2}md^2$$

$$L = n\hbar$$

$$\therefore E_n = \frac{L^2}{2I} = \frac{(n\hbar)^2}{2(\frac{1}{2}md^2)} = \underline{\underline{\frac{n^2\hbar^2}{md^2}}}$$

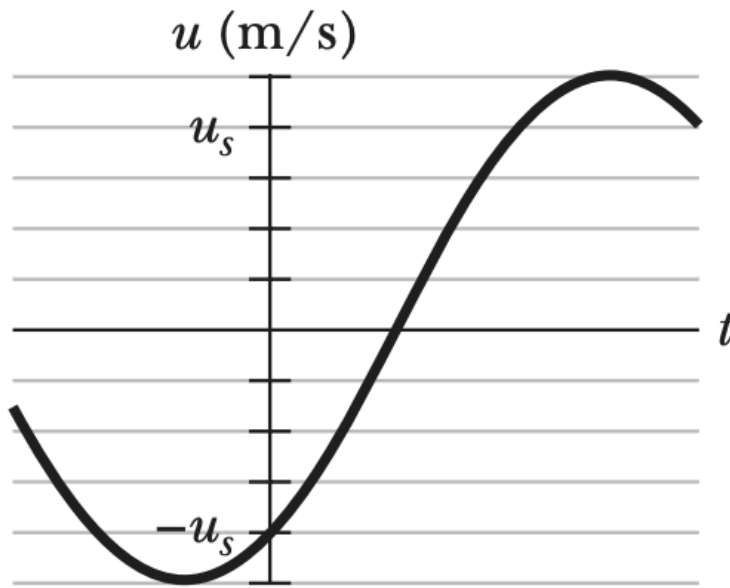
Question 3:

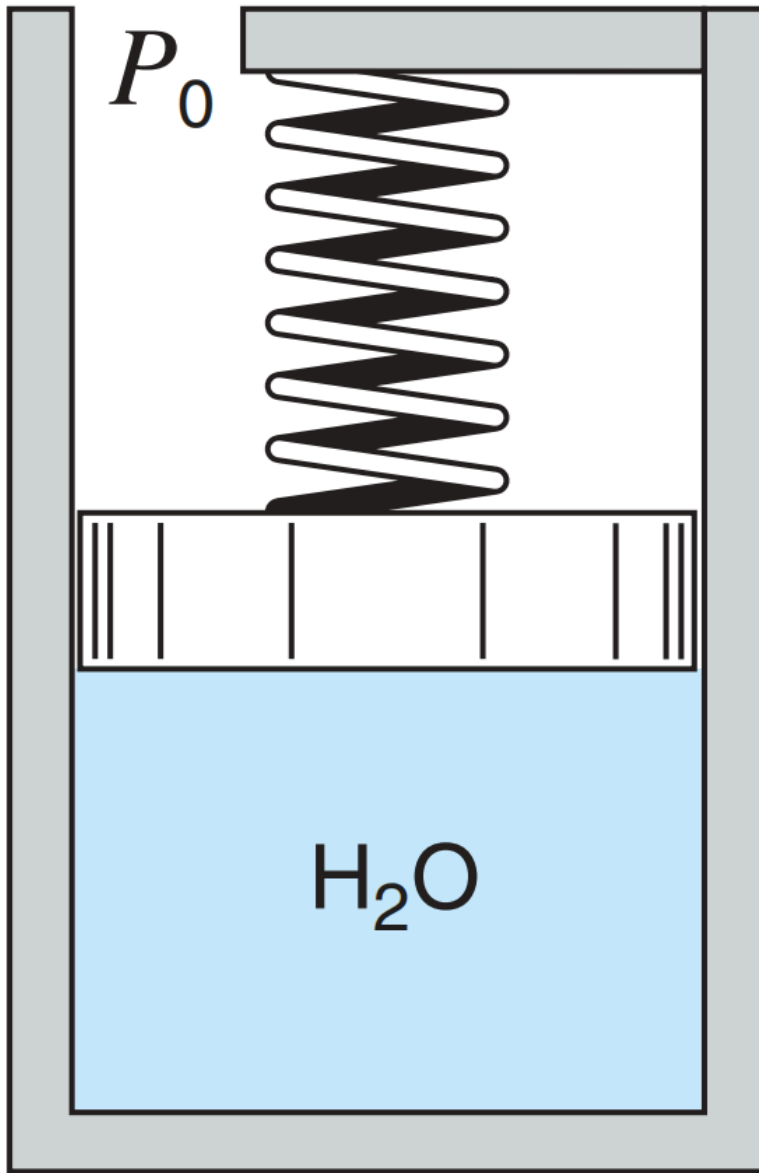
Figure shows the transverse velocity u versus time t of the point on a string at $x = 0$, as a wave passes through it. The scale on the vertical axis is set by $u_s = 4.0$ m/s. The wave has the generic form $y(x, t) = y_m \sin(kx - \omega t + \phi)$. What then is ϕ ?

$$u(x, t) = \frac{\partial y}{\partial t} \Big|_{x=0} = -\omega y_m \cos(\phi - \omega t)$$

$$\therefore u(0, 0) = 0 \Rightarrow -\omega y_m \cos \phi = 0 \Rightarrow \cos \phi = 0 \Rightarrow \phi = \frac{\pi}{2} \text{ or } \frac{3\pi}{2}$$

$$\frac{\partial u}{\partial t} = \omega^2 y_m \sin(\phi - \omega t) \xrightarrow{t=0} \frac{\partial u}{\partial t} \Big|_{t=0} = \omega^2 y_m \sin \phi$$

$$\therefore \sin \phi > 0 \Rightarrow \phi = \frac{\pi}{2} \text{ rad}$$

Question 4:

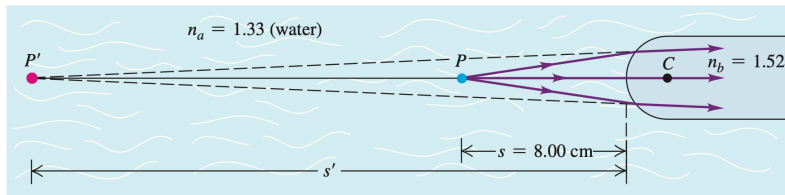
A piston/cylinder assembly contains 2 kg of liquid water at 20°C and 300 kPa, as shown in figure. There is a linear spring mounted on the piston such that when the water is heated, the pressure reaches 3 MPa with a volume of 0.1 m^3 . Find the work in the process.

$$P_{\text{avg}} = \frac{P_1 + P_2}{2} = \frac{0.3 + 3.0}{2} = 1.65 \text{ MPa}$$

$$\therefore W = \int_{V_1}^{V_2} P dV = P_{\text{avg}} (V_2 - V_1)$$

$$= 1.65 \times (0.1 - 0.002)$$

$$= \underline{\underline{1.62 \times 10^{-2} \text{ kJ}}}$$

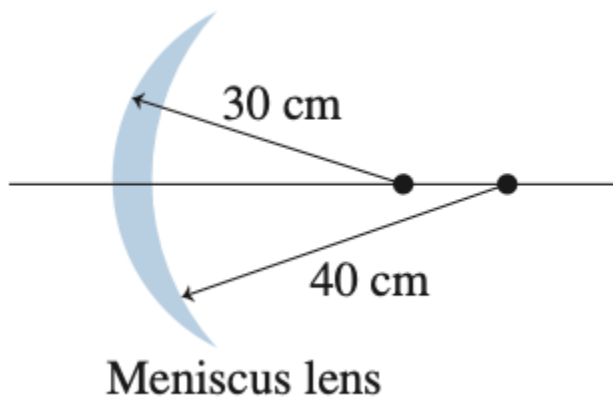
Question 5:

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

$$s' = +5.82 \text{ cm}$$

$$m = \frac{n_1 s'}{n_2 s} = -0.64$$

A cylindrical glass rod (figure) has index of refraction 1.52. It is surrounded by water that has index of refraction of 1.33. One end is ground to a hemispherical surface with radius $R = 2.00 \text{ cm}$. A small object is placed on the axis of the rod, 8.00 cm to the left of the vertex. Find the lateral magnification.

Question 6:

Find the focal length of the meniscus polystyrene plastic lens. Find the focal length of the meniscus polystyrene plastic lens

$$\begin{aligned} \frac{1}{f} &= (n-1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right) \\ &= (1.59-1) \cdot \left(\frac{1}{30} - \frac{1}{40} \right) \\ &= 0.0343 \text{ cm}^{-1} \\ \therefore f &= 29 \text{ cm} \end{aligned}$$

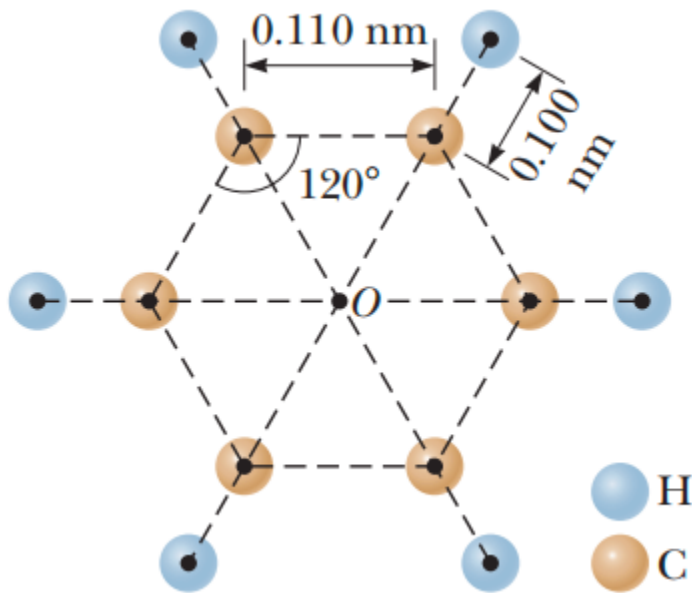
Question 7:

Figure is a model of a benzene molecule. All atoms lie in a plane, and the carbon atoms ($m_C = 1.99 \times 10^{-26}$ kg) form a regular hexagon, as do the hydrogen atoms ($m_H = 1.67 \times 10^{-27}$ kg). The carbon atoms are 0.110 nm apart center to center, and the adjacent carbon and hydrogen atoms are 0.100 nm apart center to center. Calculate the moment of inertia of the molecule about an axis perpendicular to the plane of the paper through the center point O .

- A. $2.31 \times 10^{-45} \text{ kg} \cdot \text{m}^2$
- B. $1.65 \times 10^{-45} \text{ kg} \cdot \text{m}^2$
- C. $1.05 \times 10^{-45} \text{ kg} \cdot \text{m}^2$
- ☒ D. $1.89 \times 10^{-45} \text{ kg} \cdot \text{m}^2$

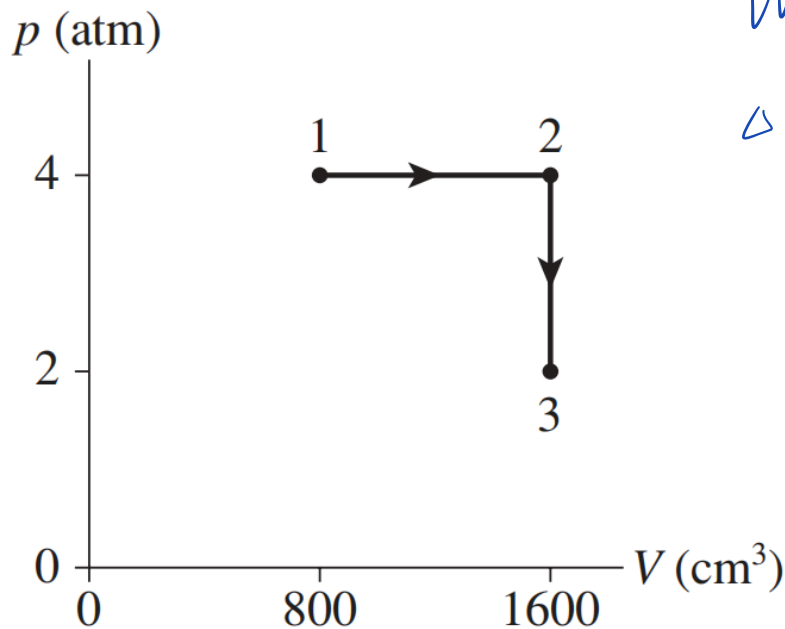
$$R_c = a = 0.11 \times 10^{-9} \text{ m}$$

$$R_H = R_c + d = 0.21 \times 10^{-9} \text{ m}$$

$$I = \sum mr^2 = 6m_C R_c^2 + 6m_H R_H^2$$

$$= 1.89 \times 10^{-45} \text{ kg} \cdot \text{m}^2$$

D

Question 8:

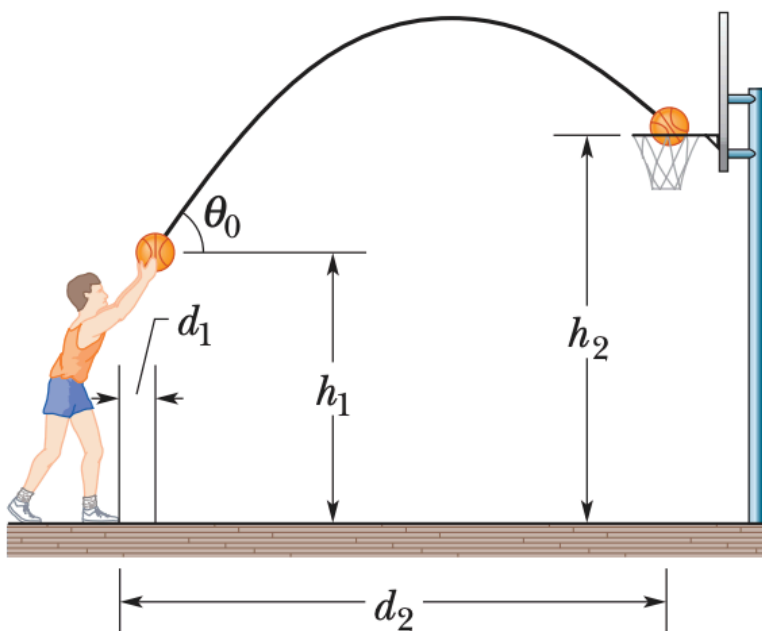
$$W_{2 \rightarrow 3} = \int_{V_2}^{V_3} P dV = 0$$

$$\Delta U_{2 \rightarrow 3} = \frac{3}{2} n R T = \frac{3}{2} \Delta P V$$

$$= \frac{3}{2} (P_3 V_3 - P_2 V_2)$$

$$= -4.8 \times 10^2 \text{ J}$$

0.10 mol of a monatomic gas follow the process shown in figure. How much heat energy is transferred to or from the gas during process $2 \rightarrow 3$?

Question 9:

$$\begin{aligned} x(t) &= v_0 \cos \theta_0 t \\ y(t) &= h_1 + v_0 \sin \theta_0 t - \frac{1}{2} g t^2 \end{aligned}$$

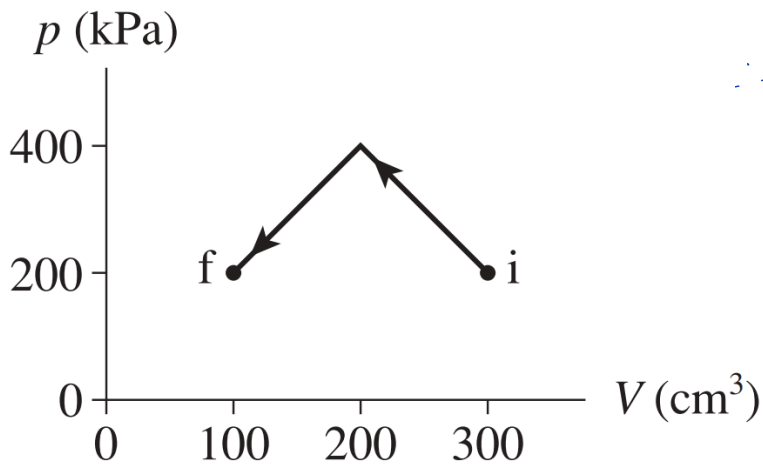
$$t = \frac{x}{v_0 \cos \theta_0} = \frac{15 \text{ ft}}{v_0 \cos 55^\circ}$$

$$\therefore h_2 = h_1 + v_0 \sin \theta_0 t - \frac{1}{2} g t^2$$

$$\therefore v_0 = 24.5 \text{ ft/s}$$

$$= 7.5 \text{ m/s}$$

The horizontal distances are $d_1 = 1.0 \text{ ft}$ and $d_2 = 14 \text{ ft}$, and the heights are $h_1 = 7.0 \text{ ft}$ and $h_2 = 10 \text{ ft}$. At what initial speed must the basketball player in figure throw the ball, at angle $\theta_0 = 55^\circ$ above the horizontal, to make the foul shot?

Question 10:

$$W = \bar{p} \Delta V.$$

$$\therefore W_{12} = \frac{1}{2}(P_1 + P_2) \cdot (V_2 - V_1)$$

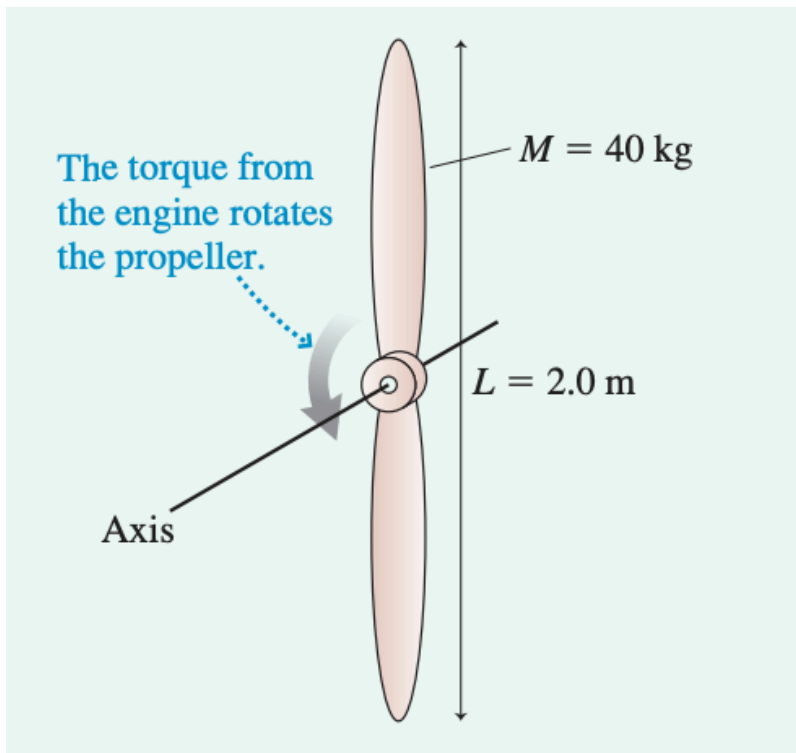
$$= -30 \text{ J}$$

$$W_{i \rightarrow f} = W_{12} + W_{23}$$

$$= -30 - 30$$

$$= \underline{\underline{-60 \text{ J}}}$$

A gas is compressed in two stages. First, its volume decreases while pressure rises. Then, its volume further decreases as pressure declines, resulting in a smaller final volume. How much work is done on the gas in the process shown in figure?

Question 11:

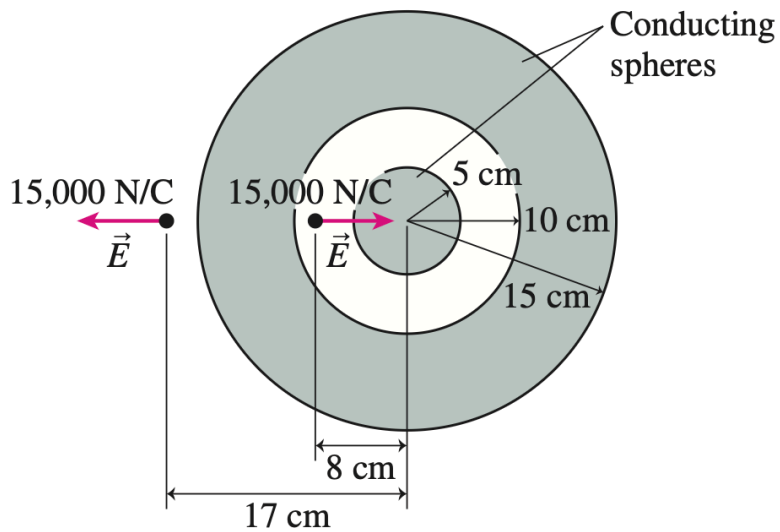
$$I_{\text{leaf}} = \frac{1}{3} \left(\frac{M}{2} \right) L^2$$

$$= \frac{1}{3} \cdot 40 \cdot 1^2 = 1.33 \times 10^1 \text{ kg} \cdot \text{m}^2$$

$$\alpha = \frac{\omega}{t} = \frac{60}{13.3} = 4.5 \text{ rad/s}^2$$

$$\therefore t = \frac{\omega}{\alpha} = \frac{20.9}{4.5} = \underline{\underline{4.65}}$$

The engine in a small airplane is specified to have a torque of 60 N m. This engine drives a 2.0 m-long, 40 kg propeller. On start-up, how long does it take the propeller to reach 200 rpm?

Question 12:

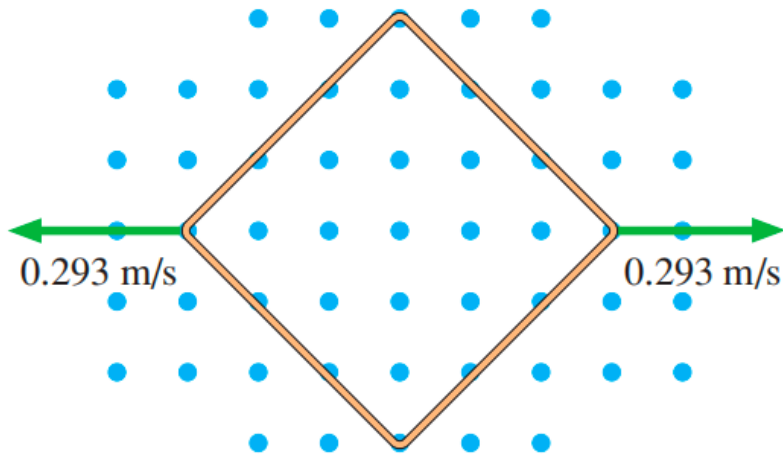
The figure shows a solid metal sphere at the center of a hollow metal sphere. What is the total charge on the inside surface of the hollow sphere?

$$\frac{Q_{in}}{\epsilon_0} = \oint \vec{E} \cdot d\vec{A}$$

$$\frac{Q_2 + Q_1}{\epsilon_0} = E \cdot 4\pi r^2$$

$$\therefore Q_1 + Q_2 = 0 \quad (E=0)$$

$$\Rightarrow Q_2 = -Q_1 = E \cdot 4\pi r^2 \cdot \epsilon_0 = \underline{\underline{+1.07 \times 10^{-8} \text{ C}}}$$

Question 13:

A closed, square loop is formed with 40 cm of wire having $R = 0.10 \, \Omega$, as shown in figure. A 0.50 T magnetic field is perpendicular to the loop. At $t = 0$ s, two diagonally opposite corners of the loop begin to move apart at 0.293 m/s. How long does it take the loop to collapse to a straight line?

A. 0.7 s

B. 0.3 s

C. 0.1 s

D. 0.9 s

$$d = 2v = 0.586 \text{ m/s}$$

$$t = \frac{d_f - d_0}{d} = 0.15$$

C

Question 14:

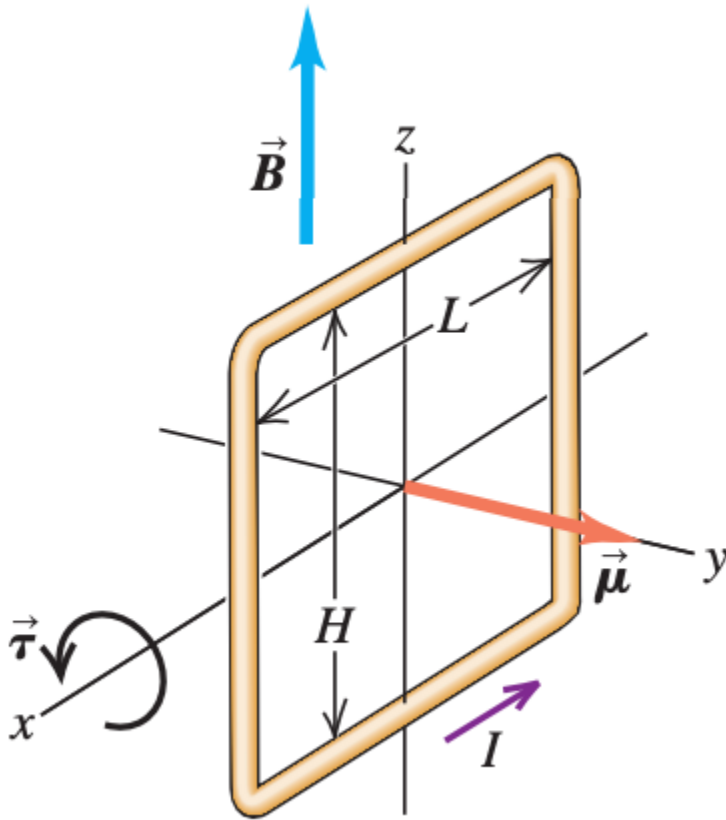
A steel wire is used to stretch the spring of figure. An oscillating magnetic field drives the steel wire back and forth. A standing wave with three antinodes is created when the spring is stretched 8.0 cm. What stretch of the spring produces a standing wave with two antinodes?

$$\lambda_n = \frac{2L}{n}, \quad \frac{v_3}{v_2} = \frac{\lambda_3}{\lambda_2} = \frac{2}{3}$$

$$v = \sqrt{\frac{T}{\mu}} \Rightarrow \frac{T_2}{T_3} = \frac{9}{4}$$

$$\frac{\lambda_2}{\lambda_3} = \frac{T_2}{T_3} \Rightarrow \lambda_2 = \frac{9}{4} \lambda_3 = \underline{\underline{0.18 \text{ m}}}$$

Question 15:

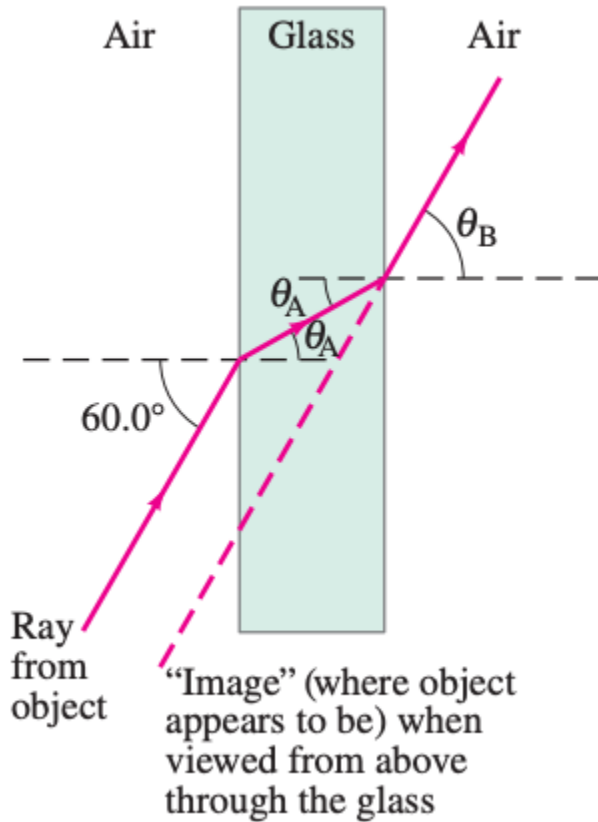


In a laboratory, a rectangular loop of wire surrounds the origin in the xz -plane, with extent H in the z -direction and extent L in the x -direction (figure). The loop carries current I in the counterclockwise direction as viewed from the positive y -axis. A magnetic field $\vec{B} = B\hat{k}$ is present. The electromagnetic field is $\vec{E} \perp \vec{B} = (0, \vec{B})$ in an inertial frame S , and then in another frame S' moving at velocity \vec{v} relative to S . What is the component of the magnetic field \vec{B}' , perpendicular to \vec{v} ?

$$\beta = \frac{v}{c} \quad , \quad \gamma = \frac{1}{\sqrt{1-\beta^2}}$$

$$\therefore B_{\perp}' = \gamma \left(B_{\perp} - \frac{v \wedge B}{c^2} \right)$$

$$= \gamma B = \frac{B}{\sqrt{1-\frac{v^2}{c^2}}}$$

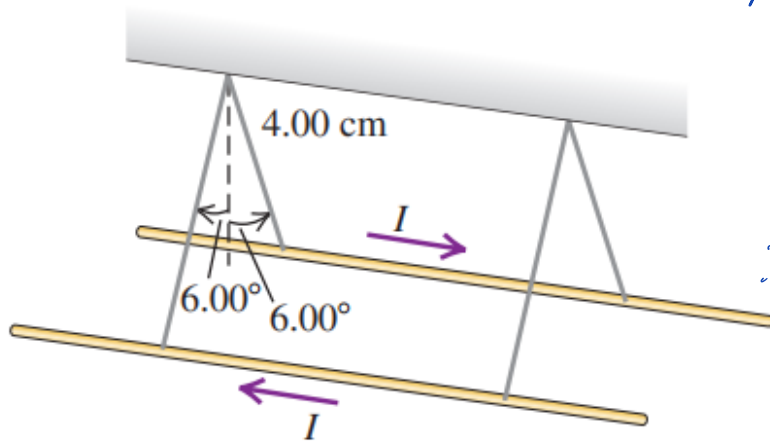
Question 16:

Light traveling in air strikes a flat piece of uniformly thick glass at an incident angle of 60.0° , as shown in figure. The index of refraction of the glass is 1.50. What is the angle θ_B at which the ray emerges from the glass?

$$n_{\text{air}} \sin \theta_1 = n_g \sin \theta_2 \Rightarrow \sin \theta_2 = 0.577 \Rightarrow \theta_2 = 35.3^\circ$$

$$n_g \sin \theta_2 = n_{\text{air}} \sin \beta \Rightarrow \sin \beta = \sin \theta_1$$

$$\Rightarrow \beta = \theta_1 = \underline{\underline{60^\circ}}$$

Question 17:

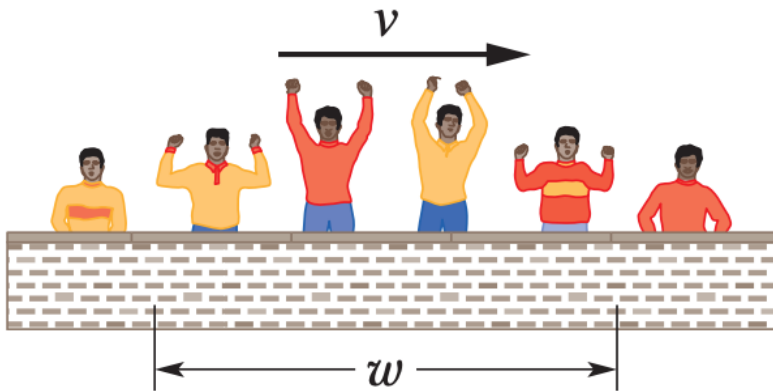
$$r = 2L \sin \theta = 8.36 \times 10^{-3} \text{ m}$$

$$\tan \theta = \frac{F_B}{F_g} = \frac{\mu_0 I^2}{2\pi r} / mg$$

$$\therefore I^2 = \frac{2\pi r m g \tan \theta}{\mu_0}$$

$$\Rightarrow I = \underline{\underline{23 \text{ A}}}$$

Two long, parallel wires hang by 4.00 cm-long cords from a common axis. The wires have a mass per unit length of 0.0125 kg/m and carry the same current in opposite directions. What is the current in each wire if the cords hang at an angle of 6.00° with the vertical?

Question 18:

During sporting events within large, densely packed stadiums, spectators will send a wave (or pulse) around the stadium. As the wave reaches a group of spectators, they stand with a cheer and then sit. At any instant, the width w of the wave is the distance from the leading edge (people are just about to stand) to the trailing edge (people have just sat down). Suppose a human wave travels a distance of 853 seats around a stadium in 39 s, with spectators requiring about 1.8 s to respond to the wave's passage by standing and then sitting. What is the width w (in number of seats)?

$$v = \frac{853}{39} = 21.9 \text{ seat/s}$$

$$w = v \cdot t = 21.9 \cdot 1.8 = \underline{\underline{39 \text{ seats}}}$$